

## REDUCTION GEAR MECHANISM

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application relates to the following U.S.

5 Patent Applications, all filed concurrently herewith on  
September 24, 2001, and all of which are expressly  
incorporated herein by reference in their entireties: "ZOOM  
LENS MECHANISM" having attorney docket No. P21180, "ZOOM  
LENS MECHANISM" having attorney docket No. P21181,  
10 "ECCENTRICITY-PREVENTION MECHANISM FOR A PAIR OF  
LENS-SUPPORTING RINGS" having attorney docket No. P21182,  
"RING MEMBER SHIFT MECHANISM AND LENS GROUP SHIFT MECHANISM"  
having attorney docket No. P21184, "LENS BARREL" having  
attorney docket No. P21185, "LENS BARREL" having attorney  
15 docket No. P21186, "LENS BARREL" having attorney docket No.  
P21187, "LENS BARREL" having attorney docket No. P21188,  
"ZOOM LENS BARREL" having attorney docket No. P21190, and  
"LENS BARREL" having attorney docket No. P21192, each naming  
as inventors Hiroshi NOMURA et al.; and "LENS DRIVE CONTROL  
20 APPARATUS FOR ZOOM LENS SYSTEM HAVING A SWITCHING LENS  
GROUP" having attorney docket No. P21189 and naming as  
inventor Norio NUMAKO.

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to a reduction gear mechanism.

## 5 2. Description of the Related Art

Conventionally, a plurality of gears is supported by respective different rotational axes in a reduction gear mechanism, which reduces the speed of a motor to transmit the driving force to components to be driven. This inevitably leads to the extensive arrangement of the series of reduction gears that extend considerably in the direction perpendicular to the rotational axes of the gears. However, it is often difficult to find a sufficiently large space to accommodate the series of reduction gears in instruments in which the reduction gears are to be arranged. For example, in the case of reduction gears provided in a telescopic portion of a zoom lens barrel between a motor and a component to be driven by the motor, the gears are sequentially arranged in a circumferential direction about an optical axis of the zoom lens. When it is desired to reduce the length of the circumference or the diameter of the lens barrel, the space in which the series of reduction gears are arranged must be kept as small as possible.

## SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a reduction gear mechanism which achieves a high degree of freedom for arranging a series of reduction gears and, in particular, helps keep the space required to arrange reduction gears as small as possible with respect to the direction perpendicular to the central axes of the gears.

In order to achieve the above-mentioned object, a reduction gear mechanism is provided, including at least first and second axes which extend parallel to each other; one of the first and second axes rotatably supports at least two gears arranged one after the other in the axial direction thereof, the at least two gears being independently rotatable with respect to each other, and the other of the first and second axes rotatably supports at least one gear; and the gears provided on the first and second axes being engaged with each other in such a manner that the gear supported on one of the first and second axes successively and alternatively engages with the gear supported on the other of the first and second axes.

In an embodiment, each of the first and second axes rotatably supports two gears arranged one after the other

in the axial direction thereof.

In an embodiment, each of the gears supported by the parallel central axes is a double gear having a larger gear portion and a smaller gear portion, the smaller gear portion  
5 of the double gear supported by one of the central axes engaging with the larger gear portion of the double gear supported by the other central axis.

In an embodiment, in each of said double gears, the larger gear engages with a preceding gear and the smaller  
10 gear engages with a succeeding gear, with respect to the direction of driving transmission.

In an embodiment, the gears supported by the central axes are identical to each other.

The reduction gear mechanism can be arranged in a lens  
15 barrel.

In an embodiment, the lens barrel includes a bi-directional motor; a first sub-lens frame and a second sub-lens frame for supporting a first sub-lens group and a second sub-lens group, respectively, the first and second  
20 sub-lens groups functioning optically in a mutually close position and in a mutually distant position, in the optical axis direction; and a sub-lens group driving mechanism which moves the first and second sub-lens frames to the mutually

close and distant positions, and moves the first and second sub-lens frames integrally in the optical axis direction in the mutually close and distant positions, as the bi-directional motor is actuated. The reduction gear  
5 mechanism is provided between the bi-directional motor and the sub-lens group driving mechanism in the zoom lens barrel.

According to another aspect of the present invention, a reduction gear mechanism is provided, including at least  
10 two gear supporting axes which extend parallel to each other; and at least three gears, a first gear and a third gear thereof being rotatably supported on the first gear supporting axis at different positions in an axial direction, the first and third gears being independently rotatable with  
15 respect to each other, and a second gear thereof being rotatably supported on the second gear supporting axis, wherein the first gear engages with the second gear, and the second gear engages with the first gear and the third gear.

In an embodiment, the reduction gear mechanism further  
20 includes a forth gear which is rotatably supported on the second gear supporting axis at a different position in the axial direction with respect to the second gear, the fourth gear being independently rotatable with respect to the

second gear, and wherein the third gear engages with the second gear and the fourth gear.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2000-289384  
5 (filed on September 22, 2000) which is expressly incorporated herein in its entirety.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic drawing of a first embodiment  
10 of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 2 is a schematic drawing of a second embodiment  
15 of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 3 is a schematic drawing of a third embodiment  
of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present  
20 invention is applied.

Figure 4 is a schematic drawing of a fourth embodiment  
of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present

invention is applied.

Figure 5 is a schematic drawing of a fifth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 6 is a schematic drawing of a sixth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 7 is a schematic drawing of a seventh embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 8 shows one example of stopping positions of the lens groups when a photographic operation is carried out, to which the present invention is applied.

Figure 9A shows an example of the stopping positions of Figure 8 and an example of an actual zoom path of the lens groups, to which the present invention is applied.

Figures 9B and 9C depict an additional schematic view of the concepts shown in Figs. 8 and 9A.

Figure 10 is a cross-sectional view showing an embodiment of a zoom lens barrel which includes the zoom lens

systems having switching lens groups shown in Figures 1, 8 and 9.

Figure 11 is a developed view of an inner surface of a cam ring of the zoom lens barrel of Figure 10 showing an exemplary arrangement of cam grooves.

Figure 12 is an exploded perspective view showing components of a switching lens group frame of the zoom lens barrel.

Figure 13 is an exploded perspective view showing some of the components of the switching lens group frame of the zoom lens barrel.

Figure 14 is a perspective view showing a different assembly of some of the components of the switching lens group frame of the zoom lens barrel.

Figure 15 is a cross-sectional view of an upper half of the switching lens group in which a first sub-lens group and a second sub-lens group are in a mutually distant position at the wide-angle extremity.

Figure 16 is a cross-sectional view of an upper half of the switching lens group in which the first sub-lens group and the second sub-lens group are in a mutually close position at the telephoto extremity.

Figure 17A is an exploded view in which components are



5           Figure 17B is a developed view showing the components  
of Figure 17A in actual engagement.

Figure 18B is a developed view showing the components of Figure 18A in actual engagement.

Figure 19B is a developed view showing the components of Figure 19A in actual engagement.

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mutually close position at the telephoto side and are focused on an object at a minimum distance.

Figure 20B is a developed view showing the components of Figure 20A in actual engagement.

5        Figure 21 is an exploded view illustrating how the mutually close position of the first sub-lens group and the second sub-lens group on the telephoto side switches to/from the mutually distant position on the wide-angle side via the rotation of an actuator ring.

10       Figure 22 illustrates how focusing is carried out by the actuator ring.

Figure 23 is an enlarged expanded view showing a face cam of a first sub-lens group frame.

15       Figure 24 is an enlarged developed view showing the relationship of the first sub-lens group frame, the second sub-lens group frame, and the actuator ring with respect to a front shutter retaining ring.

20       Figure 25 is a front view showing the relationship between the first sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows indicated by a line XXV-XXV in Figure 14.

Figure 26 is a partially enlarged view showing an encircled portion indicated by XXVI in Figure 25.

Figure 27 is a front view showing the relationship between the second sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows indicated by the line XXVII-XXVII in Figure 14.

5        Figure 28 is a partially enlarged view showing an encircled part XXVIII in Figure 27.

Figure 29 is a front view showing an arrangement of reduction gears of a reduction gear mechanism according to the present invention.

10       Figure 30 is a developed plan view of the reduction gear mechanism according to the present invention of Figure 29.

Figure 31 is a block diagram showing a control system of the zoom lens barrel shown in Figure 10.

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#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the embodiment described below, the present invention is applied to a lens barrel. This lens barrel is suitable for use with a zoom lens system proposed by the assignee of the present application in the U.S. Patent Application No.09/534,307 (Japanese Patent Application No. Hei 11-79572).

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First, embodiments of a zoom lens system with a

switching lens group proposed in the U.S. Patent Application No.09/534,307 will be herein described. U.S. Patent Application No. 09/534,307 is expressly incorporated herein by reference in its entirety.

5           Figure 1 shows the first embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group  
10   L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a negative third lens group L3. The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group  
15   frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first  
20   sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement

extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The third lens group L3 is fixed to a second lens group frame 21. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11). Throughout Figures 1 through 9, IM indicates an image plane (film surface, and so forth) which is at a predetermined position.

In the zoom paths according to the first embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), and the first sub-lens group S1 (movable sub-lens group frame 12) move in the following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the short focal length extremity  $f_w$  to an intermediate focal length  $f_m$ , the first sub-lens group S1 and the second sub-lens group S2 maintain a distance  $d_1$  therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length  $f_m$ , the first

variable lens group 10 and the second variable lens group 20 move towards the image side at the long focal-length extremity of the short-focal-length zooming range  $Z_w$ ; and the first sub-lens group S1 moves to the image-side movement  
5 extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d_2$ .

[C] In a long-focal-length zooming range  $Z_t$  from the  
10 intermediate focal length  $f_m$  to the long focal length extremity  $f_t$ , the first sub-lens group S1 maintains the shorter distance (second separation space/narrow space)  $d_2$  with respect to the second sub-lens group S2; and the first variable lens group 10 and the second variable lens group  
15 20 move towards the object, based on the positions thereof which are determined at the intermediate focal length  $f_m$ , after the first through third lens groups L1 through L3 have been moved towards the image side, while changing the distance therebetween.

20 The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 1. It should be noted, however, that the actual zoom paths are not necessarily straight

lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Figure 2 shows the second embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, a positive second variable lens group 20, and a negative third variable lens group 30, in that order from the object side. The first variable lens group 10 includes a positive first lens group L1. The second variable lens group 20 includes a negative second lens group L2 (first sub-lens group S1) and a positive third lens group L3 (second sub-lens group S2), in that order from the object side. The third variable lens group 30 includes a negative fourth lens group L4. The first lens group L1 is fixed to a first lens group frame 11. The second sub-lens group S2 of the second variable lens group 20 is fixed to a second lens group frame 21. The first sub-lens group S1 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move, in the optical axis direction, by a predetermined distance, along a guide groove

23 which is formed on the second lens group frame 21. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. The fourth lens group L4 is fixed to a third lens group frame 31. A diaphragm D is arranged to move together with the second variable lens group 20 (second lens group frame 21).

In the zoom paths according to the second embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the third variable lens group 30 (third lens group frame 31), and the first sub-lens group S1 (movable sub-lens group frame 22) move in the following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the short focal length extremity  $f_w$  to an intermediate focal length  $f_m$ , the first sub-lens group S1 and the second sub-lens group S2 maintain a distance  $d_1$  (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21) and the third variable lens



group 30 (third lens group frame 31) move towards the object side while mutually changing the distances therebetween.

[B] At the intermediate focal length  $f_m$ , the first variable lens group 10, the second variable lens group 20 and the third variable lens group 30 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range  $Z_w$ ; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 23, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d_2$ .

[C] In a long-focal-length zooming range  $Z_t$  from the intermediate focal length  $f_m$  to the long focal length extremity  $f_t$ , the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance  $d_2$ ; and the first variable lens group 10, the second variable lens group 20 and third variable lens group 30 move towards the object side based on the positions thereof which are determined at the intermediate focal length  $f_m$ , after the first through fourth lens groups 1 through 4 have been moved towards the image side, while changing the distances therebetween.

The zoom paths for the first variable lens group 10,

the second variable lens group 20 and the third variable lens group 30 are simply depicted as straight lines in Figure 2. It should be noted, however, that actual zoom paths are not necessarily straight lines.

5           Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the second variable lens group 20 (second lens group frame 21) regardless of the zooming range.

10           Likewise with the first embodiment, the zoom paths are discontinuous at the intermediate focal length  $f_m$ ; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first lens group L1, the first sub-lens group S1 (second lens group L2) and the second sub-lens group S2 (third lens group L3) and the fourth lens group L4 respectively at the short focal length extremity  $f_w$ , the intermediate focal length  $f_m$  (discontinuous line) and the long focal length extremity  $f_t$ .  
15           According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.  
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Figure 3 shows the third embodiment of the zoom lens system with a switching lens system. In this embodiment, the first lens group L1 is constructed so as to have negative

refractive power, which is the only difference compared with the second embodiment. Apart from this characteristic, the third embodiment is substantially the same as the second embodiment.

5 Figure 4 shows the fourth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes  
10 a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4  
15 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group  
20 frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is

selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fourth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame

21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the short focal length extremity  $f_w$  to an intermediate focal length  $f_m$ , the first sub-lens group S1 and the second sub-lens group S2 maintain a distance  $d_1$  therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance  $d_3$  therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length  $f_m$ , the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range  $Z_w$ ; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d_2$ , and also the third sub-lens group S3 moves toward the fourth

sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 4. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens

group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through third embodiments, in the fourth embodiment, the zoom paths are discontinuous at the intermediate focal length  $f_m$ ; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity  $f_w$ , the intermediate focal length  $f_m$  (discontinuous line), and the long focal length extremity  $f_t$ . According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 5 shows the fifth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable

lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

5           The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or  
10           the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3  
15           is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group  
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frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement  
5 extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fifth embodiment,  
10 the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the  
15 short focal length extremity  $f_w$  to a first intermediate focal length  $f_{m1}$ , the first sub-lens group S1 and the second sub-lens group S2 maintain a distance  $d_1$  therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance  $d_3$   
20 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the

distance therebetween.

[B] At the first intermediate focal length  $f_{m1}$ , the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range  $Z_w$ ; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moved toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d_2$ .

[C] In an intermediate zooming range  $Z_m$  from the first intermediate focal length  $f_{m1}$  to a second intermediate focal length  $f_{m2}$ , the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance  $d_2$ , and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the longer distance  $d_3$ ; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length  $f_{m1}$ , after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

[D] At the second intermediate focal length  $fm_2$ , the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range  $Z_m$ ; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d_4$ .

[E] In a long-focal-length zooming range  $Z_t$  from the second intermediate focal length  $fm_2$  to the long focal length extremity  $ft$ , the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance  $d_2$  therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance  $d_4$  therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the second intermediate focal length  $fm_2$ , after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10

and the second variable lens group 20 are simply depicted as straight lines in Figure 5. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

5         Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

10         Similar to the first through fourth embodiments, in the fifth embodiment, the zoom paths are discontinuous at the first intermediate focal length  $f_{m1}$  and the second intermediate focal length  $f_{m2}$ ; however, a solution for continuously forming a correct image plane exists by  
15         appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3) and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal  
20         length extremity  $f_w$ , the first and second intermediate focal lengths  $f_{m1}$ ,  $f_{m2}$  (discontinuous line), and the long focal length extremity  $f_t$ . According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can

be obtained.

Figure 6 shows the sixth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or

the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the sixth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the

short focal length extremity fw to a first intermediate focal length fm1, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the first intermediate focal length fm1, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the short-focal-length zooming range Zw; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, and wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In an intermediate zooming range Zm from the first intermediate focal length fm1 to a second intermediate focal length fm2, the first sub-lens group S1 and the second

sub-lens group S2 maintain the longer distance  $d1$  therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance  $d4$  therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length  $fm1$ , after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

[D] At the second intermediate focal length  $fm2$ , the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range  $Zm$ ; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, and wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space)  $d2$ .

[E] In a long-focal-length zooming range  $Zt$  from the second intermediate focal length  $fm2$  to the long focal length extremity  $ft$ , the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance  $d2$  therebetween, and the third sub-lens group S3 and the fourth



sub-lens group S4 maintain the shorter distance  $d_4$  therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the  
5 second intermediate focal length  $fm_2$ , after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10  
10 and the second variable lens group 20 are simply depicted as straight lines in Figure 6. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the  
15 optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through fifth embodiments, in the  
20 sixth embodiment, the zoom paths are discontinuous at the first intermediate focal length  $fm_1$  and the second intermediate focal length  $fm_2$ ; however, a solution for continuously forming a correct image plane exists by

appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity  $f_w$ , the first and second intermediate focal lengths  $f_{m1}$ ,  $f_{m2}$  (discontinuous line), and the long focal length extremity  $f_t$ . According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 7 shows the seventh embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a positive first lens group L1 (first sub-lens group S1), a negative second lens group L2 (second sub-lens group S2) and a positive third lens group L3 (third sub-lens group S3), in that order from the object side. The second variable lens group 20 includes a negative fourth lens group L4. The first sub-lens group S1 and the third sub-lens group S3 are fixed to a first lens group frame 11. The second sub-lens group S2 is mounted on a movable sub-lens group frame 12.

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The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The second sub-lens group S2 is selectively moved to either the object-side movement extremity at which the movable sub lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The fourth lens group L4 of the second variable lens group 20 is fixed to a second lens group frame 21. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the seventh embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), and the second sub-lens group S2 move in the following manner:

[A] In a short-focal-length zooming range  $Z_w$  from the short focal length extremity  $f_w$  to an intermediate focal length  $f_m$ , the first sub-lens group S1 and the second sub-lens group S2 maintain a shorter distance therebetween; however, the second sub-lens group S2 and the third sub-lens

group S3 maintain a longer distance therebetween; and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while changing the distance therebetween.

[B] At the intermediate focal length  $f_m$ , the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range  $Z_w$ ; and the second sub-lens group S2 moves to the image-side movement extremity of the guide groove 13, and wherein the second sub-lens group S2 moves away from the first sub-lens group S1 and moves toward the third sub-lens group S3.

[C] In a long-focal-length zooming range  $Z_t$  from the intermediate focal length  $f_m$  to the long focal length extremity  $f_t$ , the first sub-lens group S1 and the second sub-lens group S2 maintain the longer distance therebetween, and the second sub-lens group S2 and the third sub-lens group S3 maintain the shorter distance therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the intermediate focal length  $f_m$ , after the first through fourth lens groups L1

through L4 have been moving towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 7. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 through the third sub-lens group S3, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through sixth embodiments, in the seventh embodiment, the zoom paths are discontinuous at the intermediate focal length  $f_m$ ; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth lens group L4, respectively, at the short focal length extremity  $f_w$ , the intermediate focal length  $f_m$ , (discontinuous line), and the long focal length extremity  $f_t$ . According to such a zoom

path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

As can be understood from the above description, it is practical to apply the above-described zoom lens system having switching lens groups to a photographing lens system of a camera in which the photographing lens system and a finder optical system are independently provided. Moreover, with respect to each of the first through fourth lens groups L1 through L4, stopping positions at which the lens group stops upon zooming are preferably determined in a stepwise manner along a fundamental zoom path, i.e., it is preferable to provide a plurality of focal-length steps. Figures 8 and 9 show zoom lens systems in which positions for stopping each lens group are determined in a stepwise manner along the fundamental zoom paths. Since these zoom lens systems are the same as that of the first embodiment, identical components are provided with the same designators. The zoom paths are depicted with fundamental dotted lines; and positions at which the first lens group frame 11 and the second lens group frame 21 stop are indicated with black dots along the dotted lines. Further, in Figure 9A, the dots are connected by smooth (continuous) curved lines to form an actual zoom path. The actual mechanical structure thereof

allows the first lens group frame 11 and the second lens group frame 21 to be moved along the smooth curved lines (actual zoom path).

In the first through seventh embodiments, each lens group is illustrated as a single lens element; however, a lens group can of course include a plurality of lens elements.

Figures 9B and 9C depict an additional schematic view of the concepts shown in Figs. 8 and 9A. It should be noted in the following explanation that Figures 9B and 9C are schematic in nature (e.g., not to scale and/or not depicting actual shape) and that one skilled in the art will recognize that the zoom paths are not necessarily straight, and the manner in which the schematics of Figs. 9B and 9C relate to a designed (zooming) cam groove shape (which will differ depending at least on the optical configuration). As shown in Fig. 9B and 9C, if, in order to arrange movement in accordance with Fig. 9A, it is determined that one zoom path will be connected in an uninflected line (i.e., essentially without discontinuity or inflection and without switching), then the cam ring, shape, and orientation of cam groove(s) can be adapted for this purpose. As shown in Fig. 9B, each of the three fundamental zoom paths can include a

discontinuity. By smoothly connecting one zoom path, in this case the second zoom path (e.g., depicted in the Figures 9B and 9C by shifting all of the zoom paths in the intermediate-to-telephoto range "up" so that the path of the second lens group is connected), it becomes possible to carry out the movements of the combined groups more simply. In this case, it is decided to use "switching" for the first group and a smooth inflection in the second group. As noted, the stepwise movement/positioning and prohibition of photography in the switching/inflection range also form part of this system.

Although Fig. 9C depicts a shift in which the second zoom path is made essentially connected, the amount of shifting "up" does not need to fully align the curve to be made smoother, but need only take up a portion of the discontinuity (e.g., reducing any inflection to a selected amount, such as an imperceptible amount). In the following description, it is noted that cam groove 44f is essentially without discontinuity or inflection, relating to the second group zoom path in Figs. 9A-9C, and that cam groove 44r has a small inflection, relating to the third group zoom path in Figs. 9A-9C. However, the adaptation depicted in Figs. 9B and 9C can be used for any of the systems depicted in Figs.



1-7 or variations thereof.

It can be decided to use at least one smooth or uninflected line for various reasons, including simplicity of movement, simplicity of manufacturing, or to improve exterior appearance of movement of lens barrels (e.g., to avoid visible discontinuity in the operation of the lens barrels, so that an unsophisticated operator does not become concerned about the proper operation of the camera). In the example given, the movement of the lens barrel supporting the second lens group is essentially continuous, while the switching movement of the first lens group and the inflected movement of the third lens group cannot be seen from the exterior of the camera.

In each of the above-described embodiments, the first variable lens group 10 in Figures 1, 8, and 9A-9C, the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (including the first lens L1 and the third lens L3 as a unit) are each switching lens groups which serve as focusing lens groups in any focal length range.

A preferred embodiment will now be described in which the present invention has been applied to the zoom lens barrel in the examples shown in Figures 1, 8, and 9A-9C, which have a first variable lens group 10 (switching lens group) and a second variable lens group 20.

Figures 10 through 31 show an embodiment of a zoom lens barrel (system). Unlike the zoom lens systems shown in Figures 1, 8 and 9, in which one of the first and second sub-lens groups S1 and S2, which together form a switching lens group 10, is fixed to the first lens group frame 11, the first and second sub-lens groups S1 and S2 in this embodiment are both movable with respect to the switching lens group frame in the optical axis direction. In this embodiment, a moving path of the switching lens group frame upon zooming and a path of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame can be added to each other to give a composite zoom path, which corresponds to the zoom path shown in Figures 1, 8, and 9A-9C. Upon focusing, the first sub-lens group S1 and the second sub-lens group S2 are integrally moved within the switching lens frame in the optical axis direction. In a photographic operation, the first sub-lens group S1 and the second sub-lens group S2 are placed at a

predetermined position, before the release of the shutter is started, as a result of the movement of the switching lens group frame and the movement of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame in accordance with focal length information set by an operator (the photographer) and object distance information detected.

As shown in Figure 10, a stationary barrel 42, which is fixed to a camera body 41, has a female helicoid 43 formed on an inner surface of the stationary barrel 42. A male helicoid 45, which is formed on the rearmost circumference of a cam ring 44, engages with the female helicoid 43. Arranged outside of the stationary barrel 42 is a pinion 47 which is rotated by a zooming motor 46. Gear teeth (not shown) are formed on the circumference of the cam ring 44 wherein a part of the male helicoid 45 is cut out therefor. The gear teeth, which are formed to have the same oblique direction as the lead of the male helicoid 45, engages with the pinion 47. Accordingly, the cam ring 44 advances or retreats along the optical axis direction when the cam ring 44 is rotated in either direction by the zooming motor 46 due to the engagement of the female helicoid 43 and male helicoid 45. The position of the cam ring 44 resulting from

the rotation made by the zooming motor 46 is detected by focal length detecting device 46C, which can include, for example, of a code plate and a brush.

A linear guide ring 48 is supported by the cam ring  
5 44. The guide ring 48 rotates relative to the cam ring 44 and moves together with the cam ring 44 along the optical axis direction (i.e., no relative displacement is allowed in the optical axis direction). The guide ring 48 is supported by a camera body 41 in a manner that enables the  
10 guide ring 48 to move only in the optical axis direction. Arranged inside of the cam ring 44 in order from the front side of the cam ring 44 are a switching lens group frame 50 (first lens group frame) which supports the first variable lens group 10 (i.e., the first sub-lens group S1 and second  
15 sub-lens group S2) and a second lens group frame 49 which supports the second variable lens group 20. The switching lens group frame 50 and the second lens group frame 49 are linearly guided along the optical axis direction by the guide ring 48.

20 Cam grooves 44f and 44r are formed on an inner surface of the cam ring 44. The cam grooves 44f and 44r receive the switching lens group frame 50 and second lens group frame 49, respectively. Figure 11 shows an arrangement of the cam

grooves 44f and 44r in a developed view. Three sets of the cam grooves 44f and 44r are formed circumferentially with each groove spaced at equi-angular distances from one another. Radial follower pins 50p and 49p are provided on the switching lens group frame 50 and the second lens group frame 49 to be received in the cam grooves 44f and 44r, respectively.

The cam grooves 44f and 44r include introducing portions 44f-a and 44r-a for the follower pins 50p and 49p, retracted portions 44f-r and 44r-r for the zoom lens system, wide-angle extremity portions 44f-w and 44r-w, and telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle  $\theta_1$  is defined as the rotational angle from the introducing portions 44f-a and 44r-a to the retracted portions 44f-r and 44r-r, respectively. A rotational angle  $\theta_2$  is defined as the rotational angle from the retracted portions 44f-r and 44r-r to the wide-angle extremity portions 44f-w and 44r-w, respectively. A rotational angle  $\theta_3$  is defined as the rotational angle from the wide-angle extremity portions 44f-w and 44r-w to the telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle  $\theta_4$ , defined as the rotational angle beyond the telephoto extremity portions 44f-t and 44r-t, which

serves as a rotational angle for assembly use. Each of the cam grooves 44r for the second lens group frame 49 has an intermediate discontinuous position fm that corresponds to the zoom path of the second variable lens group 20 as described in the embodiments in Figures 1, 8 and 9.

In contrast, no discontinuous position appears to exist in the cam grooves 44f for the first variable lens group 10 between the wide-angle extremity portion 44f-w and the telephoto extremity portion 44f-t since the change in shape (profile) of each cam groove 44f is smooth in this area. This is because, in this embodiment, the switching lens group frame 50 and the sub-lens group S2 are moved in such a manner that the positions of the sub-lens group S2 are not discontinuous in the short-focal-length zooming range Zw and in the long-focal-length zooming range Zt, the two ranges extending on both sides of intermediate focal length fm in Figure 1. A connection line CC is schematically shown in Figure 1. The connection line CC connects the zoom path of the short-focal-length zooming range Zw to zoom path of the long-focal-length zooming range Zt, the two ranges extending on both sides of the intermediate focal length fm. The cam groove 44f is shaped to correspond to the zoom path connected by the connection line CC. As the follower pin

50p moves along a section corresponding to the connection line CC, the sub-lens group S1 moves from the object-side movement extremity to the image-side movement extremity. It is necessary to control the zoom lens barrel so that the section of the cam groove 44f corresponding to the line CC is not used as an actual zooming range in a photographic operation (i.e., the cam ring 44 is not stopped). Alternatively, the cam groove 44f can include the discontinuous position similar to that of the cam groove 44r.

In the above-described zoom lens barrel, the cam ring 44 advances or retreats along the optical axis while rotating as the pinion 47 is rotated via the zooming motor 46 in either direction, which causes the switching lens group frame 50 (i.e., the first variable lens group 10) and the second lens group frame 49 (i.e., the second variable lens group 20), which are guided in the optical axis direction within the cam ring 44, to move in the optical axis direction along a predetermined path defined by the cam grooves 44f and 44r.

Novel features of the present embodiment reside in a support structure by which the first sub-lens group S1 and the second sub-lens group S2 are supported in the switching

lens group frame 50 and the driving structure thereof. A particular example of an arrangement within the switching lens group frame 50 will now be described by reference to Figures 12 through 31.

5 As shown in Figures 15 and 16, a front shutter retaining ring 51, a rear shutter retaining ring 52, a first sub-lens group frame 53, a second sub-lens group frame 54, an actuator ring 55, and a gear holding ring 56 are arranged within the switching lens group frame 50. The front shutter  
10 retaining ring 51, the rear shutter retaining ring 52, and the gear holding ring 56 form a portion of the switching lens group frame 50. The first sub-lens group S1 is fixed to the first sub-lens group frame 53, and the second sub-lens group S2 is fixed to the second sub-lens group frame 54. The first  
15 sub-lens group frame 53, the second sub-lens group frame 54, and the actuator ring 55 are movably fitted in a central opening 51p (see Figure 12) of the front shutter retaining ring 51. These movable members, i.e., the first sub-lens group frame 53, the second sub-lens group frame 54, and the  
20 actuator ring 55, enable the first sub-lens group S1 and the second sub-lens group S2 to be at a mutually close position, or be at a mutually distant position, with respect to the optical axis direction, and also enable the first sub-lens



group S1 and the second sub-lens group S2 to perform focusing.

The actuator ring 55 is rotatably supported between the front and rear shutter retaining rings 51 and 52 with the rearmost portion of the actuator ring 55 being restricted by a receiving surface 52a (Figures 13, 15, and 16) of the rear shutter retaining ring 52. The actuator ring 55 is a driving member that enables the first sub-lens group S1 and the second sub-lens group S2 to become mutually close or mutually distant from each other, and enables the first and the second sub-lens groups S1 and S2 to perform focusing via the rotation thereof. The gear holding ring 56 is fixed to the front end of the front shutter retaining ring 51, and a lens shutter mechanism 57 and a diaphragm mechanism 58 are supported by the rear shutter retaining ring 52 (Figures 12, 15, and 16).

The first sub-lens group frame 53 has a cylindrical shape and has two linear guide ribs 53a on its periphery at the opposite sides thereof at an equi-angular interval of 180 degrees. A guide bore 53b is formed in the guide rib 53a. A guide rod 59 is loosely inserted (or moveably fitted) in the guide bore 53b. The rear end of the guide rod 59 is fixed in a fixing bore 56q formed at the rearmost

portion of the gear holding ring 56 while the front end of the guide rod 59 is fixed to the front surface of the gear holding ring 56 by a bracket 60 and a screw 61. A coil spring 62 is placed over each of the guide rod 59 between the bracket 60 and the guide rib 53a so that the coil spring 62 biases the first sub-lens group frame 53 toward the second sub-lens group frame 54. A U-shaped recess 56r is provided on the gear holding ring 56 so as to receive the guide rod 59 and the spring 62 (Figures 25 through 27). The recess 56r communicatively connects with the central opening 51p of the front shutter retaining ring 51. The first sub-lens group frame 53 can be connected to the front shutter retaining ring 51 by engaging the guide ribs 53a with the guide rods 59 of the front shutter retaining ring 51 at two positions, wherein the guide ribs 53a are provided on the first sub-lens group frame 53 at 180° intervals about the optical axis.

As shown in Figures 17A, 18A, 19A and 20A, the first sub-lens group frame 53 is provided with four shift leading surfaces (shift cam surfaces) 53c that are formed circumferentially at equi-angular intervals on the end-face of the first sub-lens group frame 53. Annular light-blocking support ribs 53d (see Figure 14) are provided

radially outside of the shift leading surfaces 53c over the open ends of the shift leading surfaces 53c. Figure 23 shows an enlarged expanded view of one of the shift leading surfaces 53c which is formed essentially as a straight slope having an inclination angle  $\alpha$  with respect to a circumferential edge of the first sub-lens group 53 (i.e., with respect to a plane normal to the optical axis), and is provided with a pair of follower engaging recesses 53e and 53f on either end of the shift leading surface 53c. Each of the engaging recesses 53e and 53f is formed as a shallow V-shaped recess. The follower engaging recess 53e defines a mutually distant position on the wide-angle side and the follower engaging recess 53f defines a mutually close position on the telephoto side, of the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and second sub-lens group S2).

As shown in Figures 17A, 18A, 19A and 20A, the second sub-lens group frame 54 is provided on its periphery with four follower projections 54a, each corresponding to each of the four shift leading surfaces 53c of the first sub-lens group frame 53. An inclined surface 54b is provided so as to correspond to the shift leading surface 53c of the first sub-lens group frame 53, and the follower projection 54a is

provided on the end of the inclined surface 54b which is the closest to the shift leading surface 53c. The tip of the follower projection 54a has a substantially semi-circular shape which is symmetrical with respect to the longitudinal axis thereof, so that the shapes of the engaging recesses 53e and 53f correspond to the tip shape of the projection 54a. Annular light-blocking support ribs 54c are radially provided on the second sub-lens group frame 54 inside the projections 54a and the inclined surfaces 54b. The shift leading surfaces 53c formed on the first sub-lens group frame 53 and the follower projections 54a formed on the second sub-lens group frame 54 together form a shift cam mechanism (of a lens group shift mechanism) that enables the lens-group frames 53 and 54 either be at a mutually close position, or be at a mutually distant position. As described above, the four shift leading surfaces 53c of the first sub-lens group frame 53 and the four projections 54a of the second sub-lens group frame 54 are spaced at equi-angular intervals. Accordingly, each of the surfaces can engage with its respective projection at  $180^\circ$  intervals of a relative rotation. Given that N is the number of the shift leading surfaces 53c or the follower projections 54a (four, in this embodiment) and that M is the number of the

guide ribs 53a of the first sub-lens group frame 53 or the number of the guide rods 59 of the front shutter retaining ring 51 (two, in this embodiment), the relationship between M and N is that M is a multiple of N, or in other words, N is a divisor of M. This relationship makes it possible to select an assembly position from among different assembly positions, so that for example, an assembly position that provides optimum optical performance can be achieved.

Furthermore, a pair of linear guide projections 54d are formed on the second sub-lens group frame 54 on the outer surface thereof. The guide projections 54d are formed at the same circumferential positions as two of the four follower projections 54a that are positioned on the periphery of the second sub-lens group frame 54 at the opposite sides thereof at an equi-angular interval of 180 degrees. Each of the guide projections 54d is formed at a position which is rearward with respect to the follower projection 54a in the optical axis direction. Also formed on the second sub-lens group frame 54 on the outer surface thereof are three lugs 54e, which are spaced at equi-angular intervals, and are positioned rearward with respect to the guide projection 54d in the optical axis direction. As best shown in Figure 24, each lug 54e has a pair of contact

surfaces N1 and N2 that are spaced apart from each other in a circumferential direction. Each lug 54e also has a smooth circular shaped end surface N3 that is symmetrical with respect to the central axis of the lug 54e extending in the middle of the contact surfaces N1 and N2.

As shown in Figure 24, a pair of rotation preventing surfaces 51a and 51b are formed on the front shutter retaining ring 51 on the inner surface thereof, in order to define the range of rotation of the second sub-lens group frame 54 relative to the non-rotating front shutter retaining ring 51, with respect to the guide projection 54d of the second sub-lens group frame 54. The rotation preventing surfaces 51a and 51b come into contact with contact surfaces M1 and M2 of the guide projection 54d, respectively, when the second sub-lens group frame 54 is rotated in either direction, thereby defining the rotational movement extremities of the second sub-lens group frame 54. A wide-angle linear guide slot 51d is defined between the rotation preventing surface 51a and a guide surface 51c which comes into contact with the contact surface M2 of the guide projection 54d. A telephoto linear guide slot 51f is defined between the rotation preventing surface 51b and a guide surface 51e which comes into contact

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each of the lugs 54e of the second sub-lens group frame 54 (see Figure 22). Each of the control recesses 55a has a shape that is symmetrical with respect to the central axis extending parallel to the optical axis and includes a pair of effective surfaces 55b and 55c that respectively come into contact with contact surfaces N1 and N2. The lugs 54e of the second sub-lens group frame 54 and the control recesses 55a constitute a focusing cam mechanism of a focusing mechanism. The control recess 55a also includes a pair of focus leading surfaces 55d and 55e (focus cam surfaces) on the telephoto side and on the wide-angle side, respectively. The focus leading surfaces 55d and 55e each come into contact with the circular end surface N3 of the lug 54e. The telephoto-side focus leading surface 55d and the wide-angle-side focus leading surface 55e are provided between the effective surfaces 55b and 55c in the form of an end-faced cam having an open front end. The slopes of the leading surfaces 55d and 55e have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e., the slopes both incline forwards in the optical axis direction. Annular light-blocking support ribs 55f (see Figure 13) are provided radially outside, and over the front portion, of the control



recess 55a of the actuator ring 55. The focus leading surfaces 55d and 55e, together with the lug 54e provided on the second sub-lens group frame 54, form a focus cam mechanism. As described above, the three lugs 54e of the second sub-lens group frame 54 and the three control recesses 55a of the actuator ring 55 are spaced at equi-angular intervals. In the illustrated embodiment, each of the lugs can engage with a respective recess at 120° angular intervals.

The aforementioned coil springs 62, which bias the first sub-lens group frame 53 rearward, so that the shift leading surfaces 53c contact the follower projections 54a, and the lugs 54e of the second sub-lens group frame 54 contact the telephoto side or wide-angle side focus leading surfaces 55d or 55e of the actuator ring 55. As described above, the rear end surface of the actuator ring 55 abuts the receiving surface 52a of the rear shutter retaining ring 52. Accordingly, the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 (receiving surface 52a) can be held in contact by the sole force exerted by the coil springs 62. As can be clearly seen from Figures 15 and 16, when the first sub-lens group frame 53, the second sub-lens

group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 are in engagement with each other, the front end of the second sub-lens group frame 54 is positioned inside the first sub-lens group frame 53, and the actuator ring 55 is situated on the periphery of the second sub-lens group frame 54.

Figure 21(A through H) shows the manner in which the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and the second sub-lens group S2) are moved via the effective surfaces 55b and 55c between a mutually close position on the telephoto side and a mutually distant position on the wide-angle side. Note that, solid line arrows represent the rotational direction of the actuator ring 55, in Figure 21.

The arrangement shown in Figure 21(A) is the mutually distant position on the wide-angle side, in which the effective surface 55b of the actuator ring 55 abuts the lug 54e, and the linear guide projection 54d of the second sub-lens group frame 54 is disengaged from the wide-angle linear guide slot 51d. As the actuator ring 55 rotates in a clockwise direction (i.e., moves to the right in Figure 21), the effective surface 55b biases the contact surface N1 of the lug 54e to rotate the second sub-lens group frame

54 clockwise (to the right in Figure 21) until the linear guide projection 54d abuts the rotation preventing surface 51b (Figures 21(A) through 21(C)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 (i.e., the first sub-lens group S1) follows the shift leading surface 53c, and the follower projection 54a of the second sub-lens group frame 54 so that the first sub-lens group frame 53 linearly moves closer to the second sub-lens group frame 54 (i.e., the second sub-lens group S1) (Figure 21(B)). Ultimately, the follower projection 54a engages with the follower engaging recess 53f and rearward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(C)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented, with all of the projections and the recesses in engagement. This completes the switching from the mutually distant position on the wide-angle side to the mutually close position on the telephoto side, resulting in the first sub-lens group S1 being in a mutually close

position with respect to the second sub-lens group S2 (i.e., mutually close extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually close  
5 position on the telephoto side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the telephoto side focus leading surface 55d until the linear guide projection 54d engages with the telephoto linear guide slot 51f. This  
10 allows the linear projection 54d to move only in the optical axis direction (Figure 21(D)). Focusing is carried out on the telephoto side from the intermediate focal length to the long focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group 53 being moved  
15 integrally at the mutually close position via the telephoto side-focus leading surface 55d.

Once the actuator ring 55 is rotated until the effective surface 55c abuts the contact surface N2 of the lug 54e, the linear guide projection 54d of the second  
20 sub-lens group frame 54 disengages from the telephoto linear guide slot 51f (Figure 21(E)).

At this point, the rotation of the actuator ring 55 has been reversed (upon or after completion of the switching

to the mutually close position on the telephoto side). As the actuator ring 55 rotates counterclockwise (i.e., moves to the left in Figure 21), the effective surface 55c biases the contact surface N2 of the lug 54e to rotate the second sub-lens group frame 54 leftward until the contact surface M1 of the linear guide projection 54d abuts the rotation preventing surface 51a (Figures 21(F) and 21(G)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 follows the shift leading surface 53c and the follower projection 54a of the second sub-lens group frame 54 so that the first sub-lens group frame 53 linearly moves away from the second sub-lens group frame 54. Ultimately, the follower projection 54a engages with the follower engaging recess 53e and forward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(G)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented, with all of the projections and the recesses in engagement. This completes the switching from the mutually close

position on the telephoto side to the mutually distant position on the wide-angle side, resulting in the first sub-lens group S1 being in a mutually distant position with respect to the second sub-lens group S2 (i.e., mutually distant extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually distant position on the wide-angle side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the wide-angle side focus leading surface 55e until the linear guide projection 54d engages with the wide-angle linear guide slot 51d. This allows the linear projection 54d to move only along the direction of the optical axis (Figures 21(G) and 21(H)). Focusing is carried out on the wide-angle side from the intermediate focal length to the short focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group frame 53 being moved integrally at the mutually distant extremity via the wide-angle side focus leading surface 55e.

Once the actuator ring 55 is rotated until the effective surface 55c abuts the contact surface N1 of the lug 54e, the linear guide projection 54d of the second

sub-lens group frame 54 disengages from the wide-angle linear guide slot 51d, and the positions of the first sub-lens group frame 53 and the second sub-lens group frame 54 return back to the position shown at Figure 21(A).

5        Figure 22 shows the principle of how the focusing is carried out via the telephoto side-focus leading surface 55d and the wide-angle side-focus leading surface 55e. As the actuator ring 55 is rotated in a telephoto side focusing range pt (from an infinite photographic distance  $\infty$  to a  
10    minimum photographic distance (object at a minimum distance) n), with the circular end surface N3 of the lug 54e in contact with the telephoto side focus leading surface 55d, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in  
15    engagement with the telephoto linear guide slot 51f) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to thereby carry out focusing. Similarly, as the actuator ring 55 is  
20    rotated in a wide-angle side focusing range pw (from an infinite photographic distance  $\infty$  to a minimum photographic distance (object at a minimum distance) n), with the circular end surface N3 of the lug 54e in contact with the

wide-angle side focus leading surface 55e, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in engagement with the wide-angle linear guide slot 51d) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to provide focusing.

In particular, focusing on the telephoto side and focusing on the wide-angle side are achieved by controlling the number of pulses counted by a encoder 64p (see Figure 30) provided in a driving system which drives the actuator ring with respect to a reference position at which the linear guide projection 54d of the second sub-lens group frame 54 comes into contact with the rotation preventing surface 51a or 51b (i.e., the position where the rotation of the actuator ring 55 is reversed). For example, the number of pulses of the driving system required to move the focusing lens groups (i.e., the sub-lens groups S1 and S2) from a reference position to a position corresponding to a minimum photographic distance  $n$ , to a position corresponding to an infinite photographic distance  $\infty$ , and to a position corresponding to an intermediate photographic distance can be predetermined by taking the leading angles for the focus



leading surfaces 55d and 55e into consideration. Accordingly, focusing can be properly carried out in accordance with the object distance information by managing the number of the pulses of the encoder.

5 Also, in the illustrated embodiment, the slopes of the telephoto side focus leading surface 55d and the wide-angle side focus leading surface 55e of the actuator ring 55 have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e.,  
10 the slopes both incline forwards in the optical axis direction, and the lug 54e is shaped to be symmetrical with respect to the central axis extending in the middle of the contact surfaces N1 and N2 which are circumferentially spaced apart from each other. Accordingly, focusing can be  
15 carried out on the telephoto side in the same manner as on the wide-angle side. This facilitates focusing control.

Figures 17A and 17B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring  
20 51 when the first sub-lens group frame 53 (i.e., the first sub-lens group S1) and the second sub-lens group frame 54 (i.e., the second sub-lens group S2) are in the mutually distant position at the wide-angle side, and are in a

position so as to focus on an object at infinity. Figures 18A and 18B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually distant position on the wide-angle side, and are in a position so as to focus on an object at a minimum distance. Figures 19A and 19B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at infinity. Figures 20A and 20B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at a minimum distance. The first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 are shown separated in

the optical axis direction in Figures 17A, 18A, 19A and 20A, and are shown in operation in Figures 17B, 18B, 19B and 20B.

Gear teeth 55g are formed over a circumference on the rear-end periphery of the actuator ring 55. As shown in  
5 Figures 12, 29 and 30, the gear teeth 55g engage with a series of reduction gears 63a. The series of reduction gears 63a are rotated in either direction by a bi-directional motor 64 which also includes the encoder 64p. A relay gear 64q is arranged between the pinion 64r of the bi-directional  
10 motor 64 and the encoder 64p. The series of reduction gears 63a are held between the front shutter retaining ring 51 and the gear holding ring 56, and the bi-directional motor 64 is held by the rear shutter retaining ring 52. The gear teeth 55g of the actuator ring 55, which are formed over the  
15 entire periphery thereof, makes it easy for the three control recesses 55a to engage with the three lugs 54e of the second sub-lens group frame 54 at different relative rotational positions that are separated by 120°.

The lens shutter mechanism 57 and the diaphragm  
20 mechanism 58 are mounted on the rear shutter retaining ring 52. In particular, as shown in Figures 12, 15 and 16, the lens shutter mechanism 57 includes a shutter sector support plate 57a, three shutter sectors 57b, and a shutter drive

ring 57c for opening and closing the shutter sectors 57b. The diaphragm mechanism 58 includes a diaphragm sector support plate 58a, three diaphragm sectors 58b, and a diaphragm drive ring 58c for opening and closing the

5 diaphragm sectors 58b. These components are retained in the rear shutter retaining ring 52 by a sector holding ring 57d. The shutter sector 57b and the diaphragm sector 58b include a pair of dowels. One of the dowels is rotatably supported by the support plates 57a and 58a and the other

10 is rotatably fitted to the drive rings 57c and 58c. The lens shutter mechanism 57 opens and closes an aperture formed by the shutter sectors 57b as the shutter drive ring 57c is rotated. The diaphragm mechanism 58 varies the size of an aperture formed by the diaphragm sectors 58b as the

15 diaphragm drive ring 58c is rotated.

Sector gear teeth 57g are formed on a part of the periphery of the shutter drive ring 57c and engage with a series of reduction gears 63b that are sequentially arranged from a shutter drive motor 57m (see Figure 12). When the

20 shutter drive motor 57m is rotated in either direction, the aperture, which has been closed by the shutter sectors 57b, is momentarily opened and is then closed again. In the zoom lens barrel of the illustrated embodiment, the shutter

sectors 57b serve both as a variable diaphragm to provide an aperture of an arbitrary size, and as a shutter. The shutter sectors 57b are electrically controlled so that the size of the aperture of the shutter sectors 57b (aperture value) and the length of time during which the aperture is left opened (i.e., shutter speed) can be varied depending on the exposure, upon the release of the shutter. Furthermore, the diaphragm drive ring 58c includes a lug 58g on the periphery thereof. The lug 58g engages with a diaphragm-controlling cam slot 48s formed on an inner surface of the linear guide ring 48 (see Figure 10). Upon zooming, the linear guide ring 48 and the rear shutter retaining ring 52 (i.e., the diaphragm drive ring 58c) moves relative to each another in the optical axis direction. This causes the lug 58g to follow the diaphragm-controlling cam slot 48s so as to move in the circumferential direction. This in turn causes the diaphragm drive ring 58c to rotate and, as a result, the size of the aperture formed by the diaphragm sectors 58b is varied. The diaphragm sector 58b is provided to restrict the maximum value of the aperture diameter especially in the wide-angle side photographing range, and the degree of opening of the aperture is mechanically varied in accordance with the amount of

extension of the zoom lens barrel.

As shown in Figure 31, the zooming motor 46 for the cam ring 44, the bi-directional motor 64 for the actuator ring 55, and the shutter drive motor 57m for the lens shutter mechanism 57 are controlled by a control circuit (control device) 66. Focal length information 67, which is set by the user (photographer) via a zoom switch or the like, detected object distance information 68, object brightness information 69, information on rotational positions of the cam ring 44, which is provided by a focal length detecting device 46C, and information on rotational positions of the motor 64, which is provided by the encoder 64p, are inputted to the control circuit 66. The zooming motor 46, the bi-directional motor 64 and the shutter drive motor 57m are controlled according to the inputted information so that exposure is carried out under proper exposure conditions in accordance with the predetermined focal lengths. While the shutter sectors 57b serve both as a shutter and as a variable diaphragm, and the diaphragm sectors 58b restrict the aperture diameter upon photographing on the wide-angle side in this embodiment, the diaphragm sectors 58b can be provided as a motor-driven variable diaphragm mechanism.

In the illustrated embodiment, the focal length

detecting device 46C (i.e., a rotational position detecting device for the cam ring 44) detects rotational positions of the cam groove 44f which correspond to the connection line CC (see Figure 1), such that the control circuit 66 does not  
5 allow the cam ring 44 to stop in this section. If the zoom lens system is provided as a step zoom lens, positions at which the cam ring 44 stops are controlled in a stepwise manner. As described above, while the operations, corresponding to the preset focal length, distance to the  
10 object, and the brightness of the object, of the zoom lens barrel (i.e., photographing optical system) having the above-described switching lens group can be completed immediately before the shutter is released, the focal length set by an operator can be confirmed via a separate finder  
15 optical system (not shown) that is provided separate from the photographing optical system.

In the zoom lens barrel using the lens barrel for the switching lens groups, positions at which the switching lens group frame 50, the first sub-lens group frame 53, and the  
20 second sub-lens group frame 54 stop upon a photographic operation can be practically determined in a stepwise manner along the zoom path.

Note that, while the lens support/drive structure has

been described with regard to the first variable lens group 10 shown in Figures 1, 8 and 9, the mechanical construction of the above-described lens barrel is also applicable to the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (the first lens L1 is integrally formed with the third lens L3).

10 In the above-described lens barrel, the arrangement of the series of reduction gears 63a which are held between the front shutter retaining ring 51 and the gear holding ring 56 are characteristic of the present invention.

As shown in Figures 12, 29 and 30, the series of reduction gears 63a include ten gears 63a-1 through 63a-10 which are arranged sequentially from the first gear 63a-1, which engages with the pinion 64r of the bi-directional motor 64, to the tenth gear 63a-10, which engages with the gear teeth 55g of the actuator ring 55. Each of the first gear 63a-1, the second gear 63a-2 and the tenth gear 63a-10 is a single gear with a predetermined diameter, and each of the gears from the third gear 63a-3 through the ninth gear 63a-9 is a double gear consisting of a larger gear and a



smaller gear. In each of the double gears 63a-3 through 63a-9, the larger gear engages with a preceding gear in the order of the driving transmission and the smaller gear engages with a succeeding gear in the same order.

5 Each of the (four) gears from the third gear 63a-3 through the sixth gear 63a-6 is identical. The third gear 63a-3 and the fifth gear 63a-5 are rotatably supported about a common central axis 63m and are able to rotate about the common central axis 63m independently of each other. The  
10 fourth gear 63a-4 and the sixth gear 63a-6 are rotatably supported about a common central axis 63n and are able to rotate about the common central axis 63n independently of each other. The central axes 63m and 63n extend parallel to each other and to the motor shaft of the bi-directional  
15 motor 64. Each of rotational axes of the gears constituting the series of reduction gears, including the central axes 63m and 63n, extends parallel to each other. Thus, all the gears 63a-1 through 63a-10 of the series of reduction gears 63a are each rotated about the central axes that extend  
20 parallel to each other. The central axes of the gears 63a-1 through 63a-10 are parallel to the optical axis of the zoom lens system.

The third gear (first gear) 63a-3 and the fifth gear

(third gear) 63a-5, supported by the common central axis 63m, and the fourth gear (second gear) 63a-4 and the sixth gear (fourth gear) 63a-6, supported by the common central axis 63n, are arranged one after the other in the direction of the central axis, such that the smaller gear on the driving force side engages with the larger gear on the driven side. Specifically, of these four gears, the smaller gear of the third gear 63a-3, to which the driving force is first transmitted from the bi-directional motor 64, engages with the larger gear of the fourth gear 63a-4. The smaller gear of the fourth gear 63a-4 in turn engages with the larger gear of the fifth gear 63a-5, and the smaller gear of the fifth gear 63a-5 engages with the larger gear of the sixth gear 63a-6. As a result, the driving force exerted by the pinion 64r of the bi-directional motor 64 is transmitted from the third gear 63a-3 on the central axis 63m, to the fourth gear 63a-4 on the central axis 63n, then to the fifth gear 63a-5 on the central axis 63m, and then to the sixth gear 63a-6 on the central axis 63n. In other words, the driving force generated by the bi-directional motor 64 is sequentially transmitted by the gears (63a-3, 63a-5, 63a-4 and 63a-6) supported by the pair of central axes 63m and 63n without being transmitted through the same gear more than once.

With this arrangement of the series of gears 63a, arranging the four gears of the third gear 63a-3 through the sixth gear 63a-6 only requires a space for two gears in the circumferential direction about the optical axis (i.e., on a plane perpendicular to the central axes of the gears). Accordingly, less space is required in the circumferential direction to arrange a predetermined number of gears. Thus, a higher degree of freedom is achieved in arranging the reduction gears in a limited space. For example, as shown in Figure 30, a space is defined between the pinion 64r of the bi-directional motor 64 (which is the starting point of the series of reduction gears 63a) and the gear 55g of the actuator ring 55 (which is the end point of the series of reduction gears 63a) in the zoom lens barrel of the present embodiment. The space is large enough to accommodate the length of the bi-directional motor 64 as viewed in the longitudinal direction of the zoom lens barrel (the direction of the central axes of the gears). It is thus desirable to efficiently make use of this space in arranging the series of gears. With the construction of the above-described embodiment, the space is efficiently utilized in the longitudinal direction of the zoom lens barrel by arranging more than one gear on each the central

axes 63m and 63n. Accordingly, the space occupied by the series of gears 63a in the circumferential direction is reduced.

As can be understood from the above discussion, the present invention provides a reduction gear mechanism that achieves a high degree of freedom in arranging the gear components and helps keep the space required to arrange the gear components as small as possible with respect to the direction perpendicular to the central axes of rotation of the gears.

While two gears are arranged on each of the central axes 63m and 63n in the above-described embodiment, three or more gears may be arranged on each axis. For example, in the case where there is a sufficiently large space in the axial direction of the central axes 63m and 63n, the seventh gear 63a-7 and the ninth gear 63a-9 in the above-described embodiment can be arranged on the central axis 63m, and the eighth gear 63a-8 and the tenth gear 63a-10 can be arranged on the central axis 63n. In this arrangement, eight gears including the third gear 63a-3 through the tenth gear 63a-10 are advantageously arranged within a space for two gears with respect to the circumferential direction. Note that, the radii of the seventh gear 63a-7 and the succeeding gears

are each adjusted to allow the gears to engage with each other in view of the distance between the central axes 63m and 63n.

The numbers of the gears arranged on each of the pair of parallel central axes can be different. For example, the seventh gear 63a-7 in the above-described embodiment can be arranged on the central axis 63m so that three gears are supported by the central axis 63m and two gears by the central axis 63n. Alternatively, two gears can be supported on one of the central axes 63m and 63n, and only one gear can be supported on the other of the central axes 63m and 63n.

Furthermore, two or more parallel central axes can be provided to support more than one gear. For example, in addition to the above-described embodiment (i.e., third gear 63a-3 and the fifth gear 63a-5 are rotatably supported about the common central axis 63m, and the fourth gear 63a-4 and the sixth gear 63a-6 are rotatably supported about the common central axis 63n), the seventh gear 63a-7 and the ninth gear 63a-9 may further be rotatably supported by a common central axis (Q1) and the eighth gear 63a-8 and the tenth gear 63a-10 may be rotatably supported by another central axis (Q2). In this arrangement, the four parallel

central axes 63m, 63n, Q1 and Q2 support sets of the third gear 63a-3 and the fifth gear 63a-5, the fourth gear 63a-4 and the sixth gear 63a-6, the seventh gear 63a-7 and the ninth gear 63a-9, and the eighth gear 63a-8 and the tenth gear 63a-10, respectively. This arrangement further reduces the space for arranging the series of gears in the circumferential direction.

As described above, various other arrangements, other than that of the illustrated embodiment, can be applied for the gear arrangement of the motor reduction gears in accordance with the present invention, within the scope of the invention. As described above, the space occupied by the series of the reduction gears is reduced in a plane perpendicular to the central axes of the gears by increasing the number of the gears supported by the same axis. This in turn increases the space occupied by the series of the reduction gears in the direction along the central axes of the gears. The present invention makes it possible to achieve an optimal arrangement of the series of reduction gears, depending on the size of the space available for arranging gears, by adjusting the number of the gears supported by the same axis or adjusting the number of the central axes that support more than one gears.

5 The present invention is particularly suitable for use  
with precision instruments, in which the arrangements of the  
series of reduction gears tend to be limited by the  
construction of the instruments. In particular, the  
present invention is effective when applied to a reduction  
gear mechanism, such as that described in the embodiment  
above, for moving the first sub-lens group and the second  
sub-lens group (i.e., switching lens group) toward/away  
from each other to the mutually close position and the  
10 mutually distant position and moving the first and the  
second sub-lens groups integrally when they are in the  
mutually close and distant positions. It should be  
appreciated, however, that the present invention is also  
applicable to various mechanisms other than the reduction  
15 gear mechanism for the zoom lens barrel and to various  
instruments other than cameras.

Furthermore, obvious changes may be made in the  
specific embodiments of the present invention described  
herein, such modifications being within the spirit and scope  
20 of the invention claimed. It is indicated that all matter  
contained herein is illustrative and does not limit the  
scope of the present invention.